



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<b>(51) International Patent Classification <sup>6</sup> :</b> <b>A61L 25/00</b>	<b>A1</b>	<b>(11) International Publication Number:</b> <b>WO 98/44963</b> <b>(43) International Publication Date:</b> 15 October 1998 (15.10.98)
<b>(21) International Application Number:</b> PCT/US98/07226 <b>(22) International Filing Date:</b> 10 April 1998 (10.04.98)  <b>(30) Priority Data:</b> 08/835,649 10 April 1997 (10.04.97) US  <b>(63) Related by Continuation (CON) or Continuation-in-Part (CIP) to Earlier Application</b> US 08/835,649 (CIP) Filed on 10 April 1997 (10.04.97)  <b>(71) Applicant (for all designated States except US):</b> BRIGHAM & WOMEN'S HOSPITAL [US/US]; 75 Francis Street, Boston, MA 02115 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> ORGILL, Dennis, P. [US/US]; 217 Claffin Street, Belmont, MA 02178 (US). MULLIKEN, John [US/US]; 182 Lee Street, Brookline, MA 02146 (US). EHRET, Frederick, W. [US/US]; 43 Greystone Road, Malden, MA 02148 (US).  <b>(74) Agents:</b> HAMMITTE, Ann, Lamport et al.; Lahive & Cockfield, LLP, 28 State Street, Boston, MA 02109 (US).		<b>(81) Designated States:</b> CA, JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).  <b>Published</b> <i>With international search report.          Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
<b>(54) Title:</b> RESORBABLE HEMOSTATIC AGENT  <b>(57) Abstract</b> <p>A resorbable hemostatic agent comprising a delivery component, that aids in the delivery to the wound site, and an active hemostatic component that performs a role in coagulation, controls bleeding in solid tissue, and does not delay or interfere with healing is described. The viscosity of this resorbable hemostatic agent can be changed to allow for easy application at a range of temperatures. The resorbable hemostatic agent of the invention provides a biodegradable, biocompatible hemostatic agent which effectively controls bleeding in bone and other dense tissue without interfering with the subsequent healing of the tissue.</p>		

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

- 1 -

## RESORBABLE HEMOSTATIC AGENT

**Background**

5 It is beneficial to control bleeding during surgery in order to maintain adequate vision during the procedure and to avoid the serious complications incurred by blood loss. Although there are many ways to control bleeding in soft tissue, methods to achieve hemostasis in bony tissues have been limited. Furthermore, existing methods employing conventional bone wax can interfere with subsequent healing of the bony  
10 tissues.

One of the earliest solutions of hemostasis in bone was developed by Horsley and Squire. Horsley published the composition of his "antiseptic wax" as: seven parts beeswax, one part almond oil, and 1% salicylic, sterilized by boiling (Horsley, V. (1892), *Brit Med J*, 1: 1165). First report of this agent's clinical use to control bleeding  
15 from bone was made by Parker (Parker, R. (1892), *Brit Med J*, 1: 1076-7). Despite the great surgical advances of the century, current bone wax is remarkably similar to Horsley's composition: 88% refined beeswax and 12% isopropylpalmitate. (Baldauf, R. and I. Kanat (1986), *J. Foot Surg.*, 25: 456-458). Conventional bone wax has no inherent hemostatic quality; its effect is via tamponade of marrow spaces. The material  
20 is not resorbed by the adjacent bone or local surrounding tissues. Therefore, it can induce inflammatory response and inhibit bone regeneration. Furthermore, bone wax may lower the bacterial clearance in cancellous bone (Johnson, P. and Fromm, D. (1981), *Surgery*, 89(2): 206-9), or result in wax embolization (Robicsek, F. *et al.* (1981), *Ann Thorac Surg.*, 31(4): 357-9).

25 Although there have been some advances in the area of hemostatic agents for skeletal tissue, conventional bone wax continues to be the most commonly used hemostatic agent. Thus, the need exists for a composition that can easily be delivered to an osteotomy gap and that controls hemostasis of bone without delaying or inhibiting bone repair. There exists a need for an effective resorbable bone agent that has inherent  
30 hemostatic qualities, is easily delivered to the site, is compatible with osseous repair and is biodegradable.

**Summary of the Invention:**

This invention provides a resorbable hemostatic agent that is easily applied to the  
35 site of solid tissue bleeding and, further, controls hemostasis without limiting or delaying the subsequent healing of the tissue. The invention features a delivery component that can exist in either a semi-solid form or liquid form at temperatures

- 2 -

ranging from 0°C to 45°C. The change in viscosity of the delivery component at varying temperatures allows for straightforward, uncomplicated application of the hemostatic agent to the wound. Once the composition is delivered to the wound in solid or semi-solid form, the increased temperature of the body causes the delivery component to  
5 become less viscous. This aids faster reabsorption into the adjacent bone and surrounding tissues. In a preferred embodiment, the delivery component is a water soluble delivery agent, such as polyethylene glycol.

In one aspect of the invention, the delivery component comprises about 65% to about 99% by weight of the resorbable hemostatic agent, preferably about 70% to about  
10 99% by weight.

In another aspect of the present invention, the delivery component comprises a combination of a high molecular weight and a low molecular weight polyethylene glycol. Preferably, the resorbable hemostatic bone agent contains about 84% to about 89% high molecular weight polyethylene glycol and about 3% to about 15% low  
15 molecular weight polyethylene glycol. However, the proportions of high molecular weight and low molecular weight polyethylene glycols can be adjusted in order to provide easy application even when the temperature of the body being treated is elevated or reduced.

The resorbable hemostatic agent of this invention can further be used for  
20 treatment of defects to dense tissues other than bone. The hemostatic agent can also be used, for example, as a plug in bleeding muscle tissue.

The invention also features an active resorbable hemostatic component for controlling hemostasis at the wound site. This component performs an active role in coagulation, does not retard bone healing, and after delivery, it is slowly degraded and  
25 resorbed by surrounding tissue. In one embodiment, this component is in a fibrous form which adheres to the bone tissue pores and does not interfere with subsequent osseous repair. Active resorbable hemostatic components which are in fibrous form include collagen sponges, thrombin and microfibrillar collagen. In a preferred embodiment, the active hemostatic component is microfibrillar collagen (MFC). In another embodiment,  
30 the active resorbable hemostatic component is in a liquid form which fills bone tissue pores and does not interfere with subsequent osseous repair. Active resorbable hemostatic components which are in liquid form include fibrin, platelet-derived factors, and thrombin. The resorbable hemostatic agent can comprise about 1% to about 25% by weight active hemostatic component, preferably 1% to 20% by weight active hemostatic  
35 component, more preferably about 1% to 10% by weight active hemostatic agent, and most preferably about 6% to about 7% by weight active hemostatic component.

- 3 -

The present invention can also contain a biologically active healing adjunct or bone inducing or regenerating agent to further aid in the process of bone repair.

### **Brief Description of the Drawings**

5           Figure 1 illustrates the operative site, showing four 5 mm holes in frontal and parietal bones.

          Figure 2 demonstrates the average percentage of bone growth, measured as percent fill of original defects, in conventional bone wax and PEG/MFC agent treated defects versus open control defects, at Day 29.

10          Figure 3 illustrates bone growth over the 85 day study for conventional bone wax and PEG/MFC agent treated defects and unfilled defects.

          Figure 4 provides a histologic view of bony defects filled with PEG/MFC agent at Days 0.33, 7, 14, 29, 55, and 85 (4a-4f, respectively). Residual MFC remains in lower left corner of defect at 8 hr. (4a). By day 7, bone growth from margins of defect is  
15   evident and residual MFC remains in upper right corner of defect (4b). At day 14, fibrous union achieved as spongy bone growth increases, some MFC present at the base of the defect (4c). At day 29, bony islands have formed and MFC has been resorbed (4d). At day 55, fat cells fill upper portion of defect, bone remodeling evident and no MFC observed (4e).

20          Figure 5 demonstrates the location of macrophages after treatment with conventional bone wax. Macrophage-filled fibrous granulation tissue lines the margin of bone wax filled defect which shows no sign of osteoporosis at Day 29.

### **Detailed Description of the Invention**

25          This invention features a resorbable hemostatic agent comprising a delivery component, that aids in the ease of delivery to the wound site, and an active hemostatic component that controls bleeding in solid tissue by activating factors involved in coagulation and that does not delay or interfere with healing. When used for the treatment of bony defects, it does not interfere with subsequent bone repair. The  
30   delivery component can exist in semi-solid or liquid form at temperatures ranging from 0°C to 45°C. As used herein, the term "semi-solid" is intended to encompass viscous states ranging from a liquid to a stiff paste. The ability of the delivery component to change viscosity at varying temperatures allows for uncomplicated application of the resorbable bone agent in a malleable, semi-solid form to an osseous defect. Upon  
35   application to the wound site, the resorbable agent is subjected to elevated body temperature which causes the delivery component to become less viscous. In less viscous form, the delivery component is quickly reabsorbed into adjacent bone and

- 4 -

surrounding body tissue. Thus, the delivery component's limited presence at the wound site, unlike conventional bone wax, does not inhibit bony union.

Polyethylene glycol (PEG) is particularly useful as the delivery component due to its water solubility, biocompatibility, and ability to change from solid to liquid form at increased temperatures. As described in the following Examples, it has been found that polyethylene glycol is reabsorbed within several hours after the application of the hemostatic agent of the invention to bleeding bone. Since the polyethylene glycol is rapidly removed, the resorbable hemostatic agent allows for fresh blood and macrophages to infiltrate the wound site. The resorbable hemostatic bone agent can comprise about 65% to about 99% by weight of the delivery component, preferably, about 70% to about 99% by weight.

In a preferred embodiment, high molecular weight and low molecular weight polyethylene glycols are combined to form the delivery component. By combining low molecular weight polyethylene glycol, which is in liquid form at room temperature, with high molecular weight polyethylene glycol, which is a solid at room temperature, the delivery component takes on a malleable consistency. Preferably, the resorbable hemostatic composition comprises about 84% to about 89% by weight high molecular weight polyethylene glycol and about 3% to about 15% by weight low molecular weight polyethylene glycol. However, the consistency of the resorbable hemostatic bone agent can be adjusted by varying the percentages of high molecular weight and low molecular weight polyethylene glycol. The percentages of high molecular weight polyethylene glycol in the resorbable hemostatic agent can range from about 70% to about 90% by weight. The low molecular weight polyethylene glycol can comprise about 10% to about 30% by weight of the resorbable agent.

The resorbable hemostatic agent of this invention can further be used as a plug for the treatment of wounds in other dense tissues, such as muscle. For example, bleeding from puncture wounds in skeletal muscle can be stopped by filling the wound with the resorbable hemostatic agent. In addition, the viscosity of the resorbable hemostatic agent can be adjusted for treatments in which the body is exposed to elevated or reduced temperatures. For example, during cardiopulmonary bypass surgery, the body temperature is lowered to reduce the heart rate. By increasing the proportion of low molecular weight polyethylene glycol and reducing the proportion of high molecular weight polyethylene glycol, a less viscous hemostatic "plug" can be easily applied to the cold tissue. After the procedure, as the body temperature returns to normal, the polyethylene glycol is rapidly reabsorbed by the surrounding tissue.

Various low molecular weight polyethylene glycols and various high molecular weight polyethylene glycols can be used to vary the consistency of the resorbable bone

- 5 -

wax. Low molecular weight polyethylene glycols can include, for example, polyethylene glycol with an average molecular weight ranging from about 300 to about 600. The high molecular weight polyethylene glycols can include polyethylene glycol with an average molecular weight ranging from about 1000 to about 1500. Preferably, 5 PEG 400 and PEG 1450 are used in combination.

The active hemostatic component of the resorbable hemostatic agent provides an efficient mechanism for controlling bleeding at the wound site. As used herein, the term "active hemostatic component" refers to a hemostatic component which performs a role in activating coagulation factors and chemical substances which are involved in the 10 coagulation pathway. In one embodiment, the active hemostatic component stimulates or induces production of factors or chemical substances involved in coagulation. In another embodiment, the active hemostatic component accelerates the series of coagulation reactions. By performing an active role in the coagulation pathway, the hemostatic components of the present invention enhance the rate at which a clot is 15 formed and hemostasis occurs at the wound site. Active hemostatic components include microfibrillar collagen (MFC), thrombin, collagen sponge, fibrin and platelet-derived factors.

Moreover, the fibrous or liquid quality of the active hemostatic component has been found to permit easy combination with the delivery component. The liquid quality 20 is also beneficial since the liquid nature of the hemostatic component allows it to fill the pores of bleeding bone and integrate into the fiber bundles of wounded muscle tissue. The ability of the hemostatic component to flow into the pores of bleeding bone and in between fiber bundles enhances the area of wounded tissue exposed to the hemostatic component. Examples of hemostatic components which can exist in liquid form include 25 thrombin, fibrin and platelet-derived factors.

The fibrous quality of certain hemostatic components of the present invention is also beneficial since the fibrous nature allows for the hemostatic component to catch in the pores of the bleeding bone and in between the fiber bundles of wounded muscle tissue. In addition, the fibrous quality of the hemostatic agent provides a higher surface 30 to volume ratio with the wounded tissue. Examples of fibrous hemostatic components include collagen sponge, thrombin and MFC.

Another feature of the active hemostatic component is that it is slowly reabsorbed by the body during the healing process. Thus, the active hemostatic components of the present invention effectively stop bleeding in bone and then are 35 slowly degraded and reabsorbed into surrounding tissue. This reabsorption period allows for bleeding to be controlled without having the hemostatic component interfering with subsequent osteogenesis. Preferably, the reabsorption period of the

- 6 -

active hemostatic component is between about three weeks and four months, more preferably between about one month and three months, and most preferably about two months from application of the resorbable hemostatic agent. For example, collagen sponge and MFC are slowly degraded and reabsorbed by surrounding tissue over  
5 approximately a two month period.

In a preferred embodiment, MFC is the active hemostatic agent. MFC has been discovered to be effective at stopping bleeding from bone while eliciting minimal inflammatory response. In addition, MFC is easily embedded into cancellous bone when polyethylene glycol is the delivery agent. Once in place, MFC does not interfere  
10 with osteogenesis. Furthermore, MFC has been shown to be slowly removed from the wound site by natural healing processes over approximately a two month period. .

In another aspect of the invention, the resorbable hemostatic bone agent can also comprise a biologically active healing adjunct or bone inducing or regenerating substance to further aid in the process of bone repair. The term "healing adjunct", as  
15 used herein, refers to biologically active substances, such as antibiotics and anti-inflammatory drugs, that can aid in preventing infection or inflammatory response. Antibiotics can include, for example, streptomycin, tetracycline, penicillin and ampicillin. Anti-inflammatory drugs can include, for example, indomethacin. The term  
"bone inducing substance" or "bone regenerating substance", as used herein, refers to  
20 substances that can be used to aid in the process of bone repair. For example, calcium phosphate and/or hydroxyapatite can be used as bone inducing substances.

This invention is further illustrated by the following Example which should not be construed as limiting.

25 **Example I: Treatment of Bone Defects With A Polyethylene Glycol/MFC Hemostatic Agent**

We blended PEG with microfibrillar collagen (84% polyethylene glycol 1450 and 9.3% polyethylene glycol 400 and 6.7% microfibrillar collagen by weight) and  
30 compared it to commercial bone wax in full-thickness cranial defects in New Zealand white rabbits.

**Preparation of Polyethylene Glycol/MFC Hemostatic Agent**

Preparation of the composite was done by sterilizing the PEG in an autoclave,  
35 while still in a liquid state it was added to MFC (Collastat®) using sterile technique under a laboratory hood.



- 7 -

Polyethylene glycol was supplied by Sigma Chemical Company; the specifications for molecular weights used in the composite are listed below:

**Specifications (Sigma Chemical Company)**

5

Polyethylene Glycols, Carbowax®	Average Molecular Weight	Freezing Point °C	pH at 25°C, 5% Aqueous Solution	Viscosity at 210°F, Centistokes
400	380 to 420		4.5 to 7.5	
1450	1300 to 1600	43.0 to 46.0	4.5 to 7.5	25 to 32

Preparation of Drill Hole Models

Twenty-one white New Zealand rabbits (2.8 - 5.0 Kg) were kept in a facility, accredited by the American Association for the Accreditation of Laboratory Animal Care, and provided food pellets and water *ad libitum*. An intramuscular injection of 3.0-5.0 cc of Atropine (0.08 mg/ml) Xylazine (6 mg/ml), and Ketamine (50 mg/ml) was administered. The scalp hair was removed with electric clippers and the skin was prepped with 70% ethanol. A midline incision extending from parietal to nasal region was made and the scalp and periosteum was retracted laterally to expose the calvaria. A #6 round bur on a cordless low-speed drill (Dremel) run at 10,000 RPM was used to create four 5 mm diameter holes in the left and right frontal and parietal bones (Figure 1). During drilling, the site was irrigated with 0.9% NaCl solution to reduce thermal damage. The defects were obtained by angling the bit to cut through the inner cortical plate at the circumference of the hole and removing the remaining button of cortical plate with a discoid/cleoid instrument. The quality of the defect and condition of the animal was noted as "good hole", "dura tear", or "bone bleed". Care was taken to avoid trauma to the dura.

Treatment of Bone Defects with Polyethylene Glycol/MFC composition

The four defects were copiously irrigated prior to treatment. The defects were filled with equal volumes of one of two treatments, or left empty as a control. The two treatments included commercial bone wax (Ethicon®) and the PEG/MFC composite prepared as previously described. The volume of treatment used was that which could be compressed into a #4 amalgam carrier. This volume, when properly shaped, completely filled the bony defect.

- 8 -

The defects were evaluated at intervals ranging from 8 hours to 85 days. After the allotted healing time had expired, animals were again anesthetized and then euthanized with thiopental via intracardiac injection. The cranial bones were exposed and photographed. A separating disc was used to harvest a block of skull including all four defects, which was subsequently split into four individual samples each containing one defect.

Bone specimens were fixed for at least 3 days in 2% paraformaldehyde, 0.1 M cacodylic buffer, pH 7.4 on a rotating table at 4°C. Specimens were decalcified in 7.5% EDTA in 0.1 M cacodylic buffer, pH 7.4, at 4°C. Samples were placed on a shaker and the solution was changed daily for approximately 3 weeks. Samples were infiltrated with vacuum with catalyzed JB-4 Solution A according to manufacturer's directions (Polysciences, Inc.). Infiltrating solution was changed every day for three days, and then samples remained in the fourth solution for approximately 3 weeks. Samples were embedded in glycol methacrylate (JB-4, Polysciences, Inc.) at a ratio of 1.0 ml Solution B (N,N-dimethylaniline) to 30 ml Solution A (acrylic monomer, n-butoxyethanol). Serial sections, 4 µm thick, were cut transversally in the midportion of the treated defect and stained for 8 minutes with Toluidine Blue 0, pH 4.0.

An observer, masked to the type of treatment, analyzed the samples and used computer planimetry to determine the extent of new bone growth. Bone growth was estimated as percent fill, measuring the area of new bone compared to the original size of the defect. Values are expressed as mean ± standard deviation.

## Results

### Gross Appearance:

This formulation of PEG/MFC agent was initially harder than conventional bone wax but with brief kneading became softer and more malleable than bone wax. The strands of microfibrillar collagen were easily embedded into the lattice of trabeculae of cancellous bone. Both PEG/MFC and conventional bone wax effectively stopped bony bleeding caused by drilling. All animals survived to sacrifice, with no evidence of infection or hematoma.

Analysis of the defects showed that the polyethylene glycol composite was completely resorbed at time of the earliest biopsy, taken at 8 hours (n=2). Defects sampled on or before two weeks (n=12) contained a visible amount of MFC. The residual MFC was surrounded by fresh blood, mesenchymal tissue, and macrophages. Little or no MFC was observed in wounds sampled between two weeks and 55 days (n=26) and no MFC was present in specimens examined after day 55 (n=4).

- 9 -

The conventional bone wax was grossly present in all defects in which it was placed (n=10). However, wax was not directly observed in histological sections due to melting that occurred during slide processing. Defects treated with bone wax evidenced very little bony regeneration (Figure 2). Biopsies taken on Day 29 showed no new bone growth (n=6). Infiltration was limited to a moderate number of macrophages in granulation tissue lining the border of the defect. Granulation tissue was evident throughout the 85-day study.

Both PEG/MFC (n=2) and unfilled specimens (n=2) demonstrated rapid osteoblastic activity with periosteal proliferation beginning by Day 3 and the formation of woven bone and bony islands by Day 7 (n=2,2, respectively). Fibrous tissue crossed most defects by two weeks. In PEG and untreated wounds, the percent of new bone increased to day 29, after which time there was no significant difference in the amount of bony growth between the PEG/MFC treated defects,  $43 \pm 13\%$  (n=18), and the untreated defects,  $47 \pm 19\%$  (n=12) (Figure 3). Between days 29-85, new bone filled from  $41 \pm 21\%$  -  $44 \pm 7\%$  of the defect area for PEG/MFC defects (n=30) and  $44 \pm 28\%$  -  $60 \pm 0\%$  for untreated defects (n=20). During this time frame, 2 of 30 PEG/MFC treated defects achieved complete bony union and 5 of 20 control defects reached bony union (Figure 4). None of the ten bone wax treated defects evidenced bony union.

There were no gross or histologic signs of infection in any of the wounds during the study period. No giant cells were observed in PEG/MFC or control defects and very few were observed in bone wax treated sites.

These data demonstrate the compatibility of the PEG/MFC composite with bony ingrowth and repair. Bony union can also be inhibited by foreign material such as conventional bone wax. PEG is water soluble and was shown to be resorbed within 8 hours, whereas microfibrillar collagen (MFC) was slowly removed over a two-month period. None of the defects filled with conventional bone wax showed any evidence of healing.

## **Example II: A Polyethylene Glycol/Collagen Sponge Hemostatic Agent**

We blended PEG with hemostatic collagen sponge (84-89% polyethylene glycol 1450 and 9-15% polyethylene glycol 400 and 1-2% collagen sponge by weight).

### Preparation of Hemostatic Collagen Sponge.

The hemostatic collagen sponge was prepared from 1.5% bovine achilles tendon collagen (Sigma, St. Louis, MO). The bovine collagen was blended in sterile water (pH 5) to a final volume of  $0.26 \text{ ml/cm}^3$  at  $10^\circ\text{C}$  for 30 minutes. This suspension was frozen

- 10 -

and placed in a freeze dryer with a shelf temperature of -35°C for 2 hours. A vacuum of 200 m Torr was applied and the shelf temperature was increased to 0°C. This resulted in a highly porous structure with a thickness of approximately 2 mm.

5    **Preparation of Polyethylene Glycol/Collagen Sponge Hemostatic Agent**

Preparation of the composite was done by sterilizing the PEG (Sigma) in an autoclave, while still in a liquid state it was added to the collagen sponge using sterile technique under a laboratory hood. The specifications for molecular weights used in this composite are listed above in Example I.

10

**Treatment of Bone Defects with Polyethylene Glycol/Collagen Sponge composition**

Using New Zealand rabbits, drill hole models can be prepared and comparisons of treatment of bony defects can be performed as described above in Example I.

15    **Example III: A Polyethylene Glycol/Thrombin Hemostatic Agent**

PEG is blended with thrombin (84-87% polyethylene glycol 1450 and 3-11% polyethylene glycol 400 and 5-10% thrombin by weight). Thrombin is commercially available from Sigma Chemical Co. (St. Louis, MO).

20    **Preparation of Polyethylene Glycol/Thrombin Hemostatic Agent**

Preparation of the composite is done by sterilizing the PEG (Sigma) in an autoclave, while still in a liquid state it is added to the thrombin using sterile technique under a laboratory hood. The specifications for molecular weights which can be used in this composite are listed above in Example I.

25

**Example IV: A Polyethylene Glycol/Fibrin Hemostatic Agent**

PEG is blended with fibrin (84-87% polyethylene glycol 1450 and 3-11% polyethylene glycol 400 and 5-10% thrombin by weight). Fibrin is commercially available from Sigma Chemical Co. (St. Louis, MO).

30

**Preparation of Polyethylene Glycol/Fibrin Hemostatic Agent**

Preparation of the composite is done by sterilizing the PEG (Sigma) in an autoclave, while still in a liquid state it is added to the fibrin using sterile technique under a laboratory hood. The specifications for molecular weights which can be used in this composite are listed above in Example I.

35

- 11 -

**Claims**

1. A resorbable hemostatic bone agent comprising about 65% to about 99% by weight delivery component and about 1% to about 25% by weight hemostatic  
5 component, wherein said hemostatic component performs an active role in coagulation and wherein said delivery component is in a semi-solid state at temperatures ranging from 0°C to 45°C.
2. The resorbable hemostatic bone agent of claim 1, wherein said hemostatic  
10 component consists essentially of a fibrous hemostatic component.
3. The resorbable hemostatic bone agent of claim 2, wherein said fibrous hemostatic component is selected from the group consisting of microfibrillar collagen, collagen sponge and thrombin.  
15
4. The resorbable hemostatic bone agent of claim 1, wherein said hemostatic component consists essentially of a liquid hemostatic component.
5. The resorbable hemostatic bone agent of claim 4, wherein said liquid  
20 hemostatic component is selected from the group consisting of thrombin, fibrin and platelet-derived factors.
6. The resorbable hemostatic bone agent of claim 1, wherein said delivery component comprises a high molecular weight polyethylene glycol and a low molecular  
25 weight polyethylene glycol.
7. The resorbable hemostatic bone agent of claim 6 wherein said high molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 1000 to about 1450.  
30
8. The resorbable hemostatic bone agent of claim 6 wherein said low molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 300 to about 600.
- 35 9. The resorbable hemostatic bone agent of claim 1, further comprising an antibiotic or anti-inflammatory drug.

- 12 -

10. The resorbable hemostatic bone agent of claim 9 wherein said antibiotic is selected from a group consisting of streptomycin, tetracycline, penicillin and ampicillin.

5 11. The resorbable hemostatic bone agent of claim 1, further comprising a bone-inducing substance.

12. A resorbable hemostatic bone agent comprising about 70% to about 99% by weight delivery component and about 1% to about 20% by weight hemostatic  
10 component, wherein said hemostatic component performs an active role in coagulation and wherein said delivery component comprises, in combination, a higher molecular weight and a low molecular weight polyethylene glycol.

13. The resorbable hemostatic bone agent of claim 12, wherein said  
15 hemostatic component consists essentially of a fibrous hemostatic component.

14. The resorbable hemostatic bone agent of claim 13, wherein said fibrous hemostatic component is selected from the group consisting of microfibrillar collagen, collagen sponge and thrombin.  
20

15. The resorbable hemostatic bone agent of claim 12, wherein said hemostatic component consists essentially of a liquid hemostatic component.

16. The resorbable hemostatic bone agent of claim 15, wherein said liquid  
25 hemostatic component is selected from the group consisting of thrombin, fibrin and platelet-derived factors.

17. The resorbable hemostatic bone agent of claim 12 wherein said high molecular weight polyethylene glycol comprises a polyethylene glycol with an average  
30 molecular weight ranging from about 1000 to about 1450.

18. The resorbable hemostatic bone agent of claim 12 wherein said low molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 300 to about 600.  
35

19. The resorbable hemostatic bone agent of claim 12, further comprising an antibiotic or anti-inflammatory drug.

- 13 -

20. The resorbable hemostatic bone agent of claim 19 wherein said antibiotic is selected from a group consisting of streptomycin, tetracycline, penicillin and ampicillin.

5

21. The resorbable hemostatic bone agent of claim 12, further comprising a bone-inducing substance.

22. A resorbable hemostatic bone agent comprising about 84% by weight high molecular weight polyethylene glycol, about 9% to about 10% by weight low molecular weight polyethylene glycol and about 6% to about 7% by weight microfibrillar collagen.

23. A resorbable hemostatic bone agent comprising about 84% to about 89% by weight high molecular weight polyethylene glycol, about 9% to about 15% by weight low molecular weight polyethylene glycol and about 1% to about 2% by weight collagen sponge.

24. A resorbable hemostatic bone agent comprising about 84% to about 87% by weight high molecular weight polyethylene glycol, about 3% to about 11% by weight low molecular weight polyethylene glycol and about 5% to about 10% by weight thrombin.

25. A resorbable hemostatic bone agent comprising about 84% to about 87% by weight high molecular weight polyethylene glycol, about 3% to about 11% by weight low molecular weight polyethylene glycol and about 5% to about 10% by weight fibrin.

26. The resorbable hemostatic bone agent of claims 22-25 wherein said high molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 1000 to about 1450.

27. The resorbable hemostatic bone agent of claims 22-25 wherein said low molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 300 to about 600.

35

- 14 -

28. The resorbable hemostatic bone agent of claims 22-25, further comprising an antibiotic or anti-inflammatory drug.

29. The resorbable hemostatic bone agent of claim 28 wherein said antibiotic  
5 is selected from a group consisting of streptomycin, tetracycline, penicillin and ampicillin.

30. The resorbable hemostatic bone agent of claims 22-25, further comprising a bone-inducing substance.

10

31. A resorbable hemostatic agent for treatment of defects in dense tissues, wherein said resorbable hemostatic agent comprises about 65% to about 95% by weight delivery component and about 5% to about 25% by weight hemostatic component, wherein said hemostatic component performs an active role in coagulation and wherein  
15 said delivery component comprises high molecular weight and low molecular weight polyethylene glycol.

32. The resorbable hemostatic agent of claim 31 wherein said dense tissues include muscle and bone.

20

33. The resorbable hemostatic agent of claim 31 wherein said high molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 1000 to about 1450.

25 34. The resorbable hemostatic agent of claim 31 wherein said low molecular weight polyethylene glycol comprises a polyethylene glycol with an average molecular weight ranging from about 300 to about 600.

35 35. The resorbable hemostatic agent of claim 31, wherein said hemostatic component consists essentially of a fibrous hemostatic component.

36. The resorbable hemostatic agent of claim 35, wherein said fibrous hemostatic component is selected from the group consisting of microfibrillar collagen, collagen sponge and thrombin.

35

37. The resorbable hemostatic agent of claim 31, wherein said hemostatic component consists essentially of a liquid hemostatic component.



- 15 -

38. The resorbable hemostatic agent of claim 37, wherein said liquid hemostatic component is selected from the group consisting of thrombin, fibrin and platelet-derived factors.

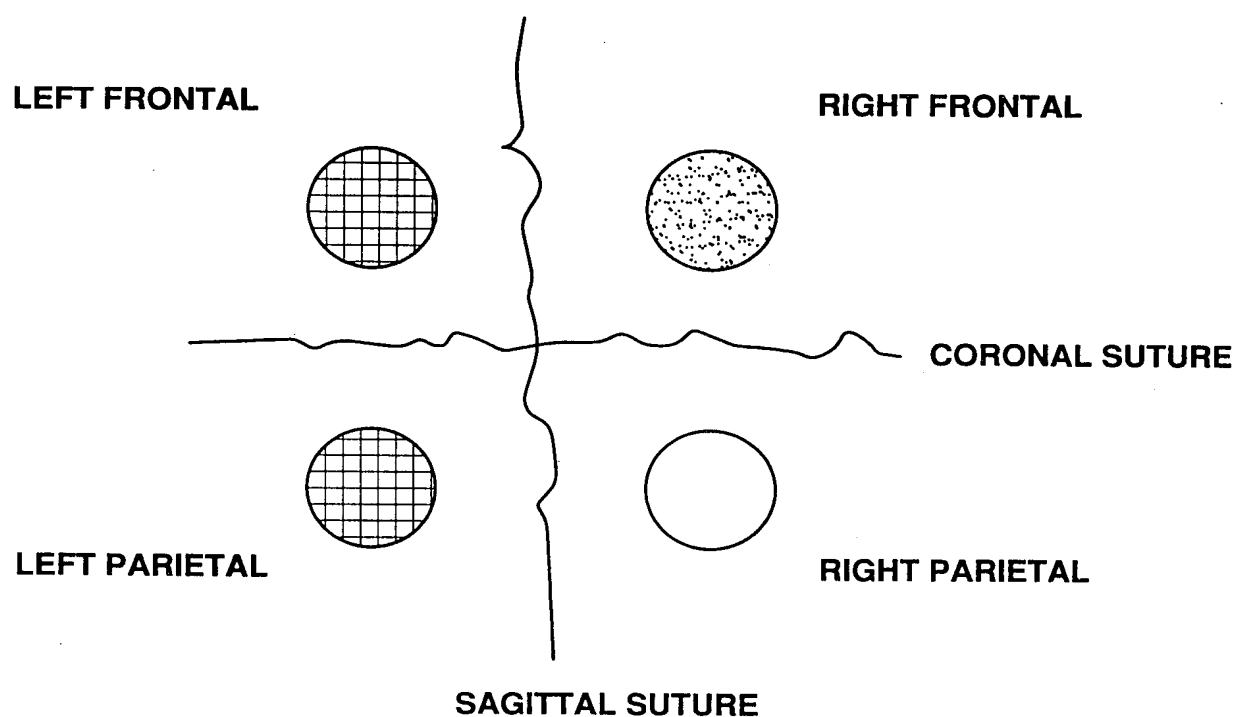
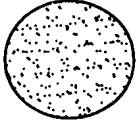
5

39. The resorbable hemostatic agent of claim 31, further comprising an antibiotic or anti-inflammatory drug.

40. A resorbable hemostatic agent of claim 31 wherein said antibiotic is  
10 selected from a group consisting of streptomycin, tetracycline, penicillin and ampicillin.

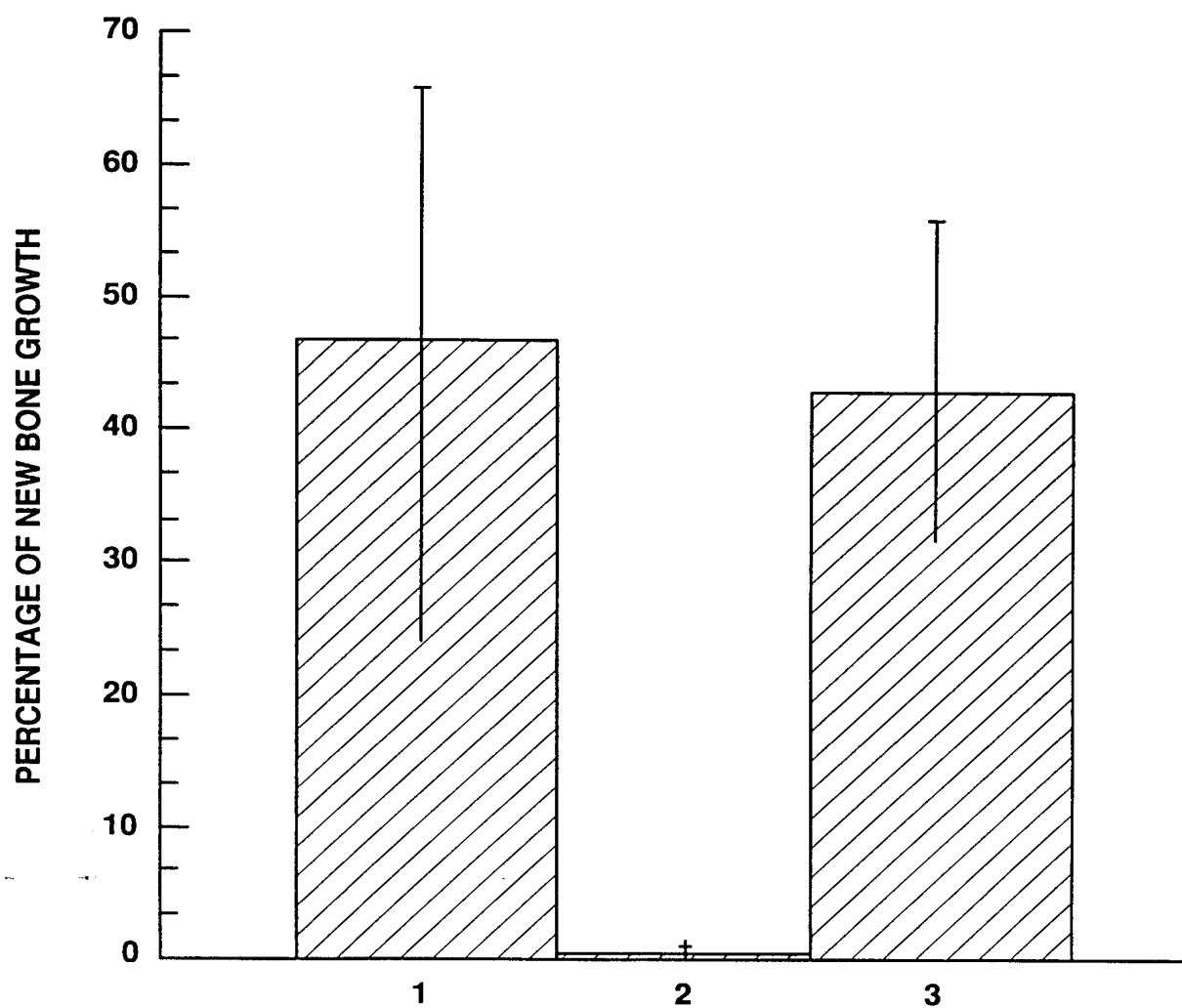
1/7

FIG. 1

 = UNFILLED (CONTROL) = PEG/MFC = BONE WAX

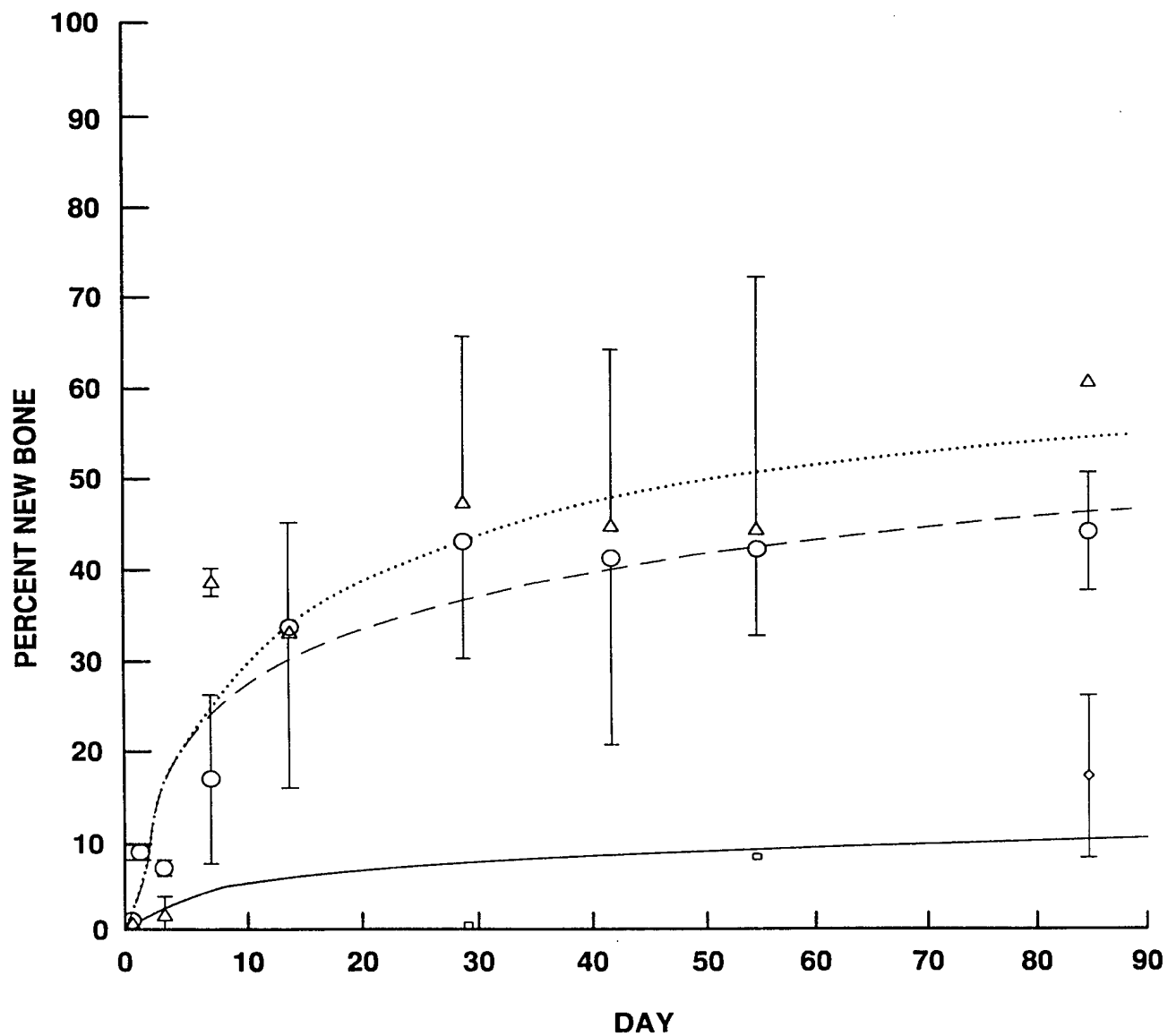
2/7

FIG. 2



3/7

FIG. 3



..... EMPTY  
----- COMPOSITE  
———— WAX

4/7

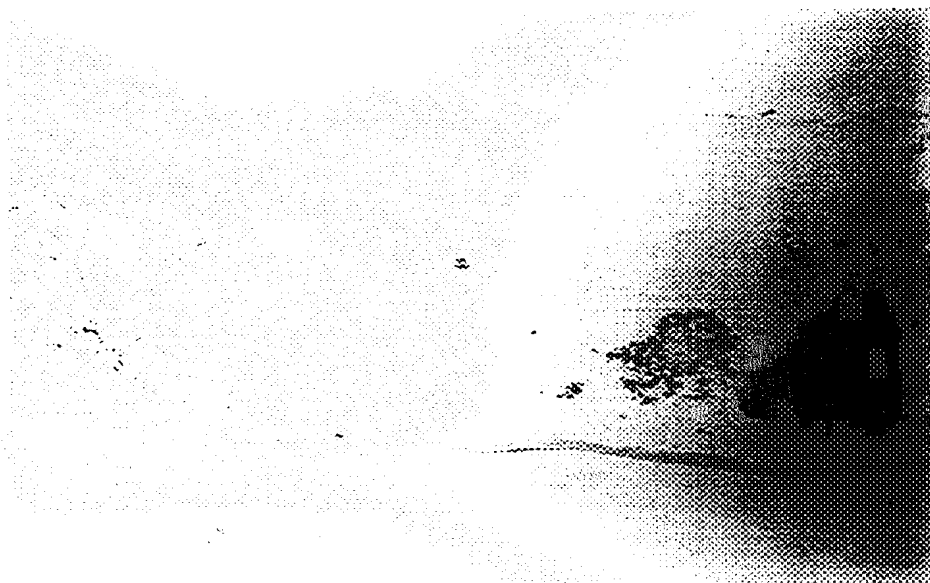


FIG. 4A



FIG. 4B

5/7

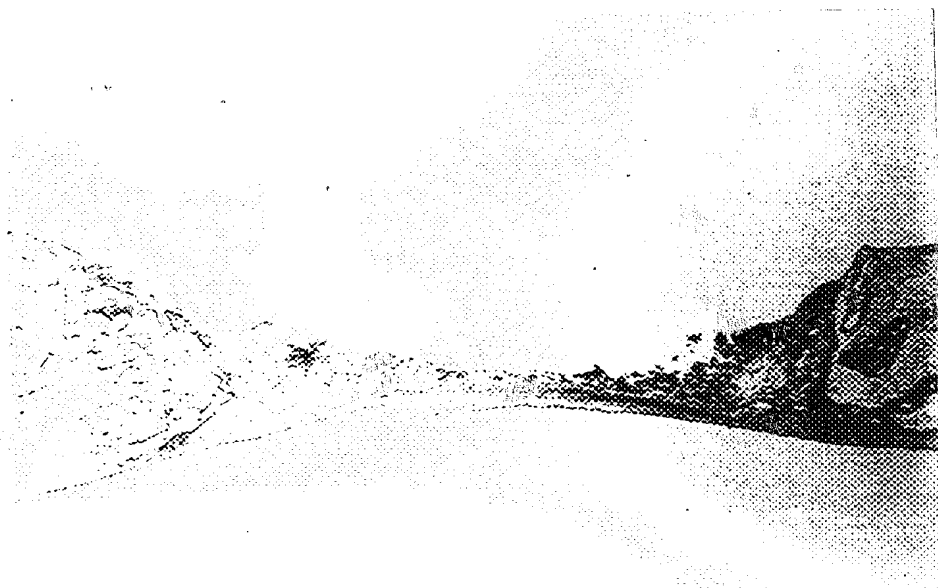


FIG. 4C

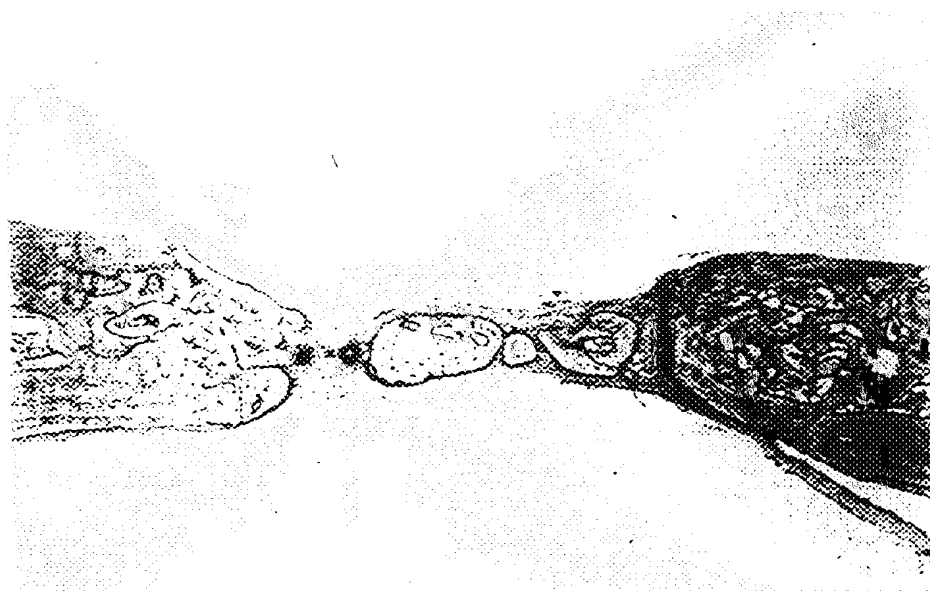


FIG. 4D

6/7

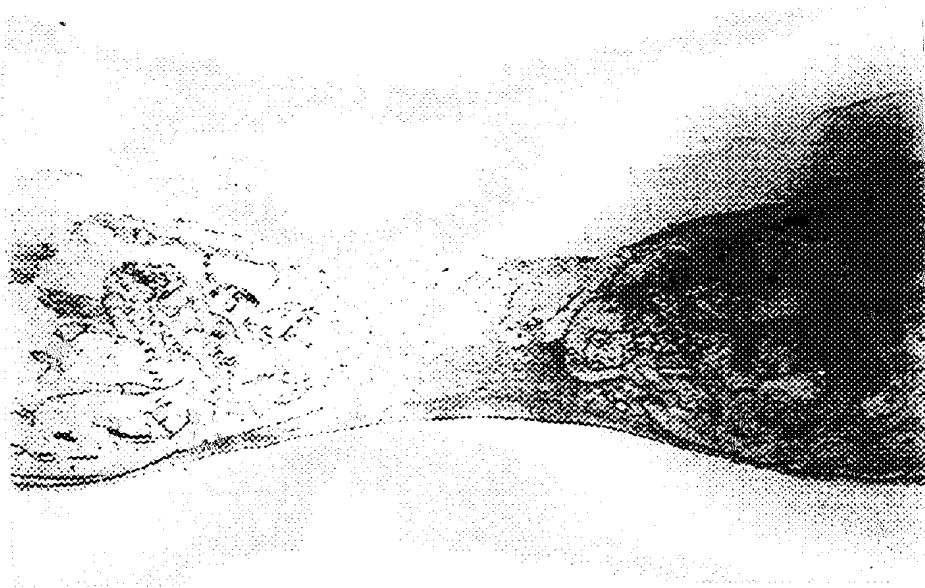


FIG.4E

7/7



FIG.5



# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 98/07226

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 6 A61L25/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 A61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 2 410 477 A (ETHICON INC) 29 June 1979  see page 2, line 27 - line 32 see page 4, line 8 - line 26 --- -/--	1-8, 11-14, 17, 18, 21, 25-27, 30-38

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- "&" document member of the same patent family

Date of the actual completion of the international search

25 August 1998

Date of mailing of the international search report

03/09/1998

Name and mailing address of the ISA  
European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,  
Fax: (+31-70) 340-3016

Authorized officer

Heck, G

# INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 98/07226

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 595 735 A (SAFERSTEIN LOWELL ET AL) 21 January 1997	1-8, 11-18, 21,24, 26,27, 30-38
Y	see column 3, line 12 - line 50  see column 1, line 42 - column 2, line 8 ---	2,3,5,9, 10,13, 14,16, 19,20, 22,23, 28,29, 35,36, 38-40
Y	WO 96 39203 A (BIOCOLL LAB INC) 12 December 1996  see examples 5,8 ---	2,3,9, 10,13, 14,19, 20,22, 23,28, 29,35, 36,39,40
Y	EP 0 560 014 A (ATRIX LAB INC) 15 September 1993  see column 12, line 5 - line 33 ---	9,10,19, 20,28, 29,39,40
Y	EP 0 383 363 A (CURATECH INC) 22 August 1990 see claims 1,3,4 -----	5,16,38

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 98/07226

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
FR 2410477	A	29-06-1979	GB 1584080 A CA 1119515 A DE 2852319 A HK 34681 A IN 149490 A	04-02-1981 09-03-1982 07-06-1979 24-07-1981 26-12-1981
US 5595735	A	21-01-1997	NONE	
WO 9639203	A	12-12-1996	AU 6107496 A EP 0851772 A	24-12-1996 08-07-1998
EP 0560014	A	15-09-1993	AU 3117493 A CA 2091552 A JP 6007423 A US 5725491 A US 5792469 A US 5632727 A	16-09-1993 13-09-1993 18-01-1994 10-03-1998 11-08-1998 27-05-1997
EP 0383363	A	22-08-1990	AU 596954 B AU 5094985 A CA 1261259 A CH 673774 A DE 3586355 A DE 3590594 T DK 357386 A,B, EP 0202298 A FI 863087 A,B GB 2248777 A,B JP 7020873 B JP 62501628 T NL 8520384 T SE 8603228 A WO 8603122 A US 4957742 A US 5178883 A US 5165938 A	24-05-1990 18-06-1986 26-09-1989 12-04-1990 20-08-1992 29-01-1987 28-07-1986 26-11-1986 28-07-1986 22-04-1992 08-03-1995 02-07-1987 29-11-1984 25-07-1986 05-06-1986 18-09-1990 12-01-1993 24-11-1992